Experiment 20: The Magnifier

EQUIPMENT NEEDED:

-Optics Bench
-150 mm Focal Length Convex Lens
-Component Holders (2)
-75 mm Focal Length Convex Lens
-Viewing Screen

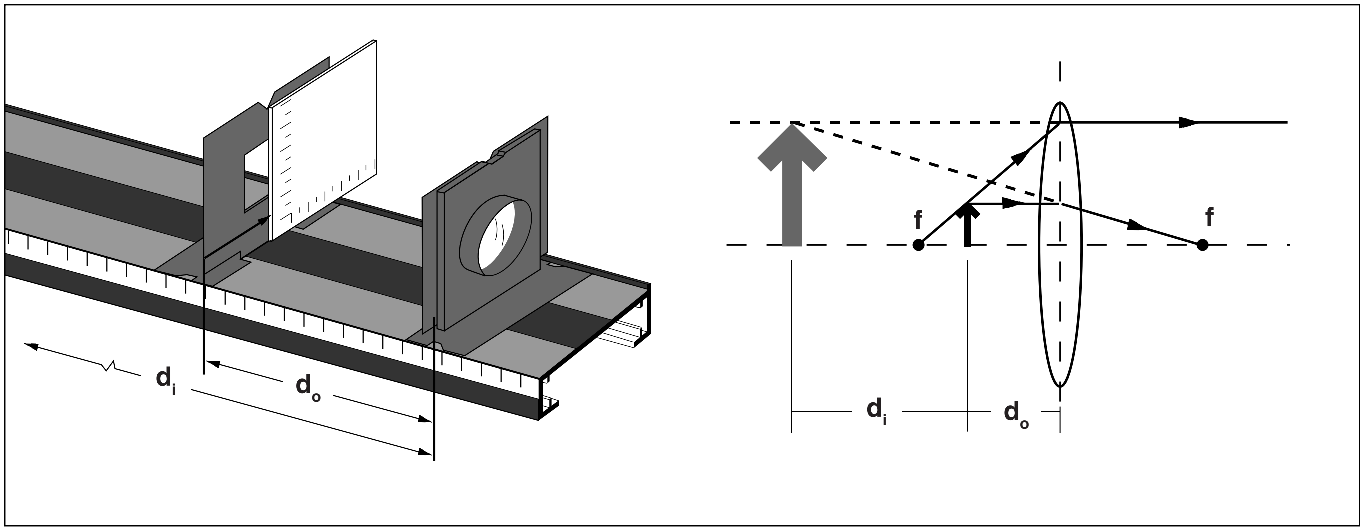

Figure 20.1 The Magnifier

Introduction

When an object is located between a converging lens and its focal point, a virtual, magnified, uninverted image is formed. Since the image is not real, it can not be focused onto a screen. However, it can be viewed directly by an observer.

Procedure

Set up a magnifier as shown in Figure 20.1 First try it with the 75 mm focal length lens, and then with the 150 mm focal length lens. For each lens, adjust the distance between the object (the Viewing Screen) and the lens so the magnification is a maximum and the image is clearly focused.

Examine Table 18.1 from Experiment 18.

① Does the Fundamental Lens Equation place any limit on the magnification, m, that a lens can produce? ______________________________

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② Looking through the lenses, which lens seems to provide the greater magnification? __________

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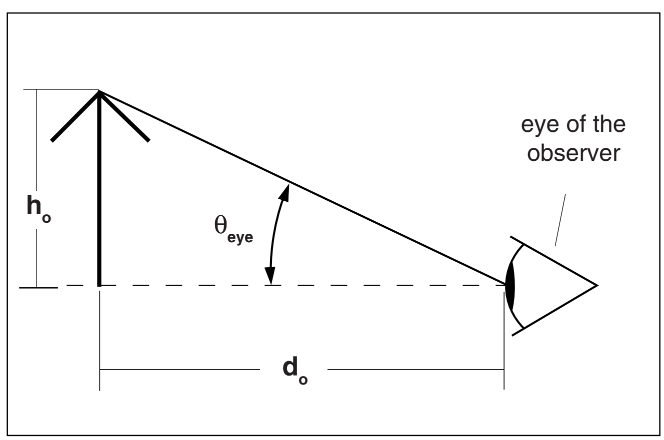

Figure 20.2 Angular Magnification

Using each of the lenses as a magnifier, it should be clear that the magnification provided by a converging lens is not unlimited. This does not mean that the equation $\mathbf{m} = -\mathbf{d_i}/\mathbf{d_o}$ is in error. This equation does give the correct ratio between the image size and the object size. However, image size is not the only important variable in determining the magnification of an optical system, such as a magnifier. Equally important is the distance between the observer and the image he is looking at. Just as a distant object appears smaller than the same object up close, an image viewed through an optical system appears larger if the image is close than if it is farther away.

Figure 20.2 shows an object of height $\mathbf{h_o}$, a distance $\mathbf{d_o}$ from the observer. The size of the image on the retina of the observer is proportional to the angle θ_{eye}. For small angles, (the only angles for which the Fundamental Lens Equation holds), $\theta_{eye} = \mathbf{h_o}/\mathbf{d_o}$.

There is an important limitation to the magnitude of θ_{eye}. To see this, hold an object at arms length and move it slowly toward your eye (with one eye closed). There is a distance—called the near point—at which the image begins to blur, because the rays entering your eye from the object are too divergent for your eye to focus. The near point differs for different people, but the average is approximately 25 cm. Therefore $\theta_{eye\text{-}max} = \mathbf{h_o}/25$ cm, where $\theta_{eye\text{-}max}$ is the maximum value of θ_{eye} for which the eye can focus an image.

When using a magnifier, or any optical system for that matter, the apparent size of the image depends on the size and location of the image rather than on the size and location of the object, so that θ_{mag}, the angular magnification for the magnifier, is equal to $\mathbf{h_i}/\mathbf{d_i}$. From the Fundamental Lens Equation $\mathbf{h_i} = \mathbf{mh_o} = (-\mathbf{d_i}/\mathbf{d_o})\ \mathbf{h_o}$. Therefore, ignoring the minus sign,
$\theta_{mag} = \mathbf{h_o}/\mathbf{d_o}$, the same as without the magnifier.

This result seems to imply that a magnifier doesn't produce any magnification. However, using a magnifier, the object can be brought closer to the eye than the near point, and yet still be focused by the eye. If the object is placed at the focal point of the magnifier for example, the equation $\theta_{mag} = \mathbf{h_o}/\mathbf{d_o}$ becomes $\theta_{mag} = \mathbf{h_o}/\mathbf{f}$. Therefore, the magnifying power of a magnifier is a function of how much closer it allows the observer to be to the object. This, in turn, is a function of the focal length of the magnifying lens.

The magnifying power of a lens (called the angular magnification) is calculated as
$\theta_{mag}/\theta_{eye\text{-}max} = 25$ cm/f.

③ Calculate the angular magnification for the 75 mm and 150 mm focal length lenses. Are your calculated magnifications consistent with your answer to question 1? ____________

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④ Would a converging lens with a 50 cm focal length be useful as a magnifier? Why or why not?

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